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# National Atmospheric Release Advisory Center (NARAC) Model Development and Evaluation

Gayle Sugiyama

April 1, 2004

9th International Conference on Harmonisation within  
Atmospheric Dispersion Modelling for Regulatory Purposes  
Garmisch-Partenkirchen., Germany  
June 1, 2004 through June 4, 2004

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*9th International Conference on Harmonisation within  
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1-4 June 2004

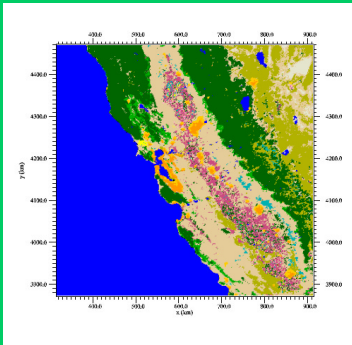
Garmish-Partenkirchen, Germany

# NARAC Provides Real-Time Assessments of Hazardous Releases



## Event information

- Real-time weather data
- Nuclear, radiological, chemical, biological source information
- Terrain, land-use, population, health effect databases



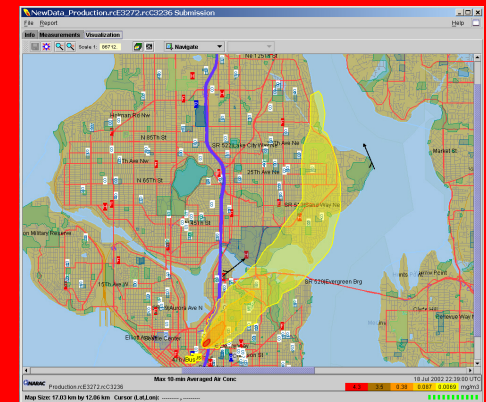
## Plume Models and Expertise

- Advanced, automated 3-D plume modeling globally relocatable in real-time
- Scientific and technical staff provides quality assurance, training, assistance and detailed analysis 24 hrs x 7 days



## Consequence Management Information

- Hazard areas
- Health effects and exposed populations
- Protective action guidelines
- GIS, facility and map features





# NARAC is a DOE/DHS Capability with a Multi-Agency Customer Base



## On-line Sites:

- ◆ DOE
- ◆ DOD
- ◆ NR

## Major Programs:

- ◆ DOE Atmospheric Release Advisory Capability(ARAC)
  - ◆ Nuclear Incident Response Team (NIRT) asset
  - ◆ FRMAC, ARG, NEST, RAP
- ◆ DHS Science & Technology (S&T)
  - ◆ DHS Operations (HSOC, FEMA)
  - ◆ Inter-Agency Modeling and Atmospheric Assessment Center (IMAAC)
  - ◆ Local Integration of NARAC with Cities (LINC)



## Advisory Services:

- ❖ FAA
- ❖ EPA
- ❖ NRC
- ❖ Local agencies

## Metadata Suppliers:

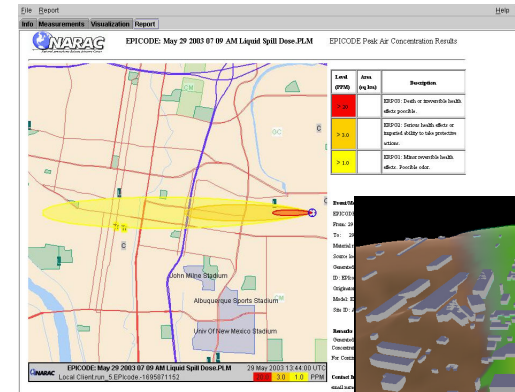
- Air Force Weather Agency (AFWA)
- Fleet Numerical Meteorology and Oceanography Center (FNMOC)
- National Weather Service
- Mesonets
- On-line sites

# Phased Modeling System Supports Different Release Types, Distance Scales, Response Times



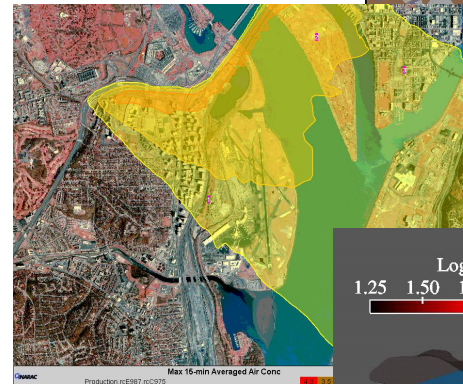
## ■ Deployable rapid-response models

- Radiological plume model HOTSPOT (Homann, 1994)
- Toxic industrial chemical model EPIcode (Homann, 1996)
- ALOHA/CAMEO (NOAA/EPA)
- INPUFF (2D puff model)



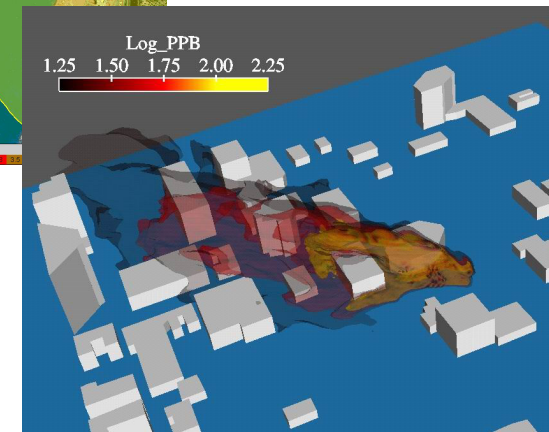
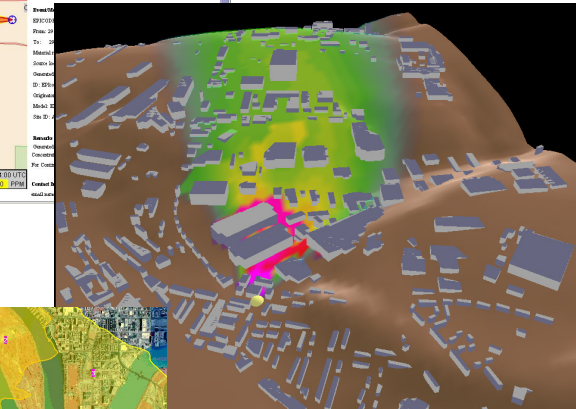
## ■ Regional-scale models

- ADAPT/LODI (coupled data assimilation/dispersion models)
- COAMPS (in-house version of NRL's weather forecast model)
- Prompt effects (SNL) and KDOFC fallout code



## ■ Building-scale CFD models

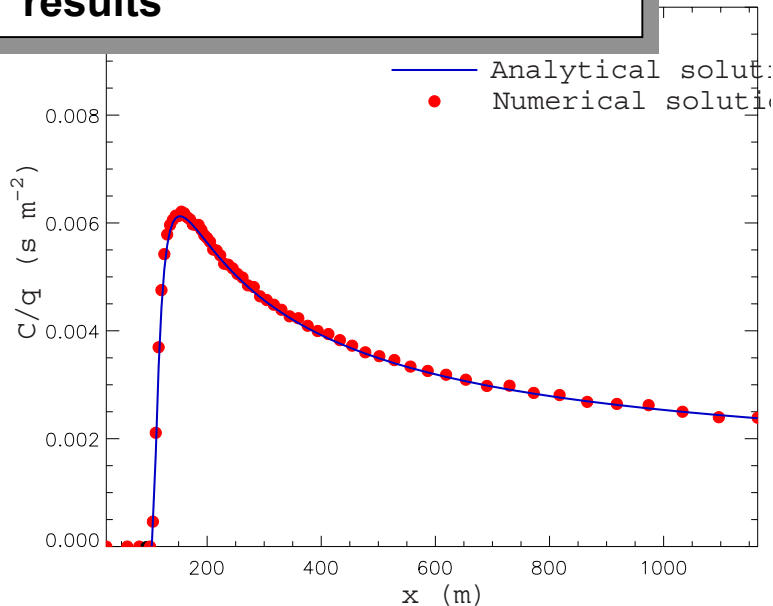
- FEM3MP ->ADM
- Empirical urban model UDM (Dstl, MOD U.K.)



# NARAC Models Have Been Extensively Tested and Evaluated

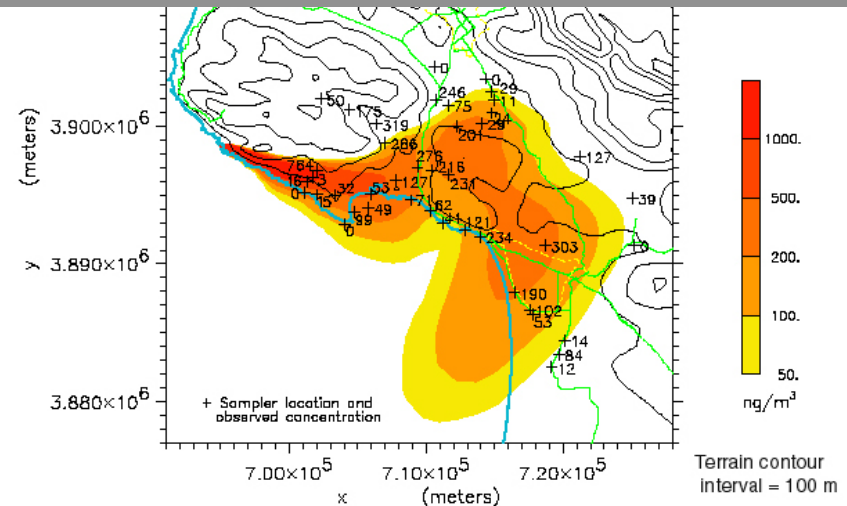


- **Analytic solutions** test models versus known, exact results



- **Field experiments** test models in real-world cases

Examples: Project Prairie Grass, Savannah River Mesoscale Atmospheric Tracer Studies, Diablo Canyon Tracer Study, ETEX, URBAN



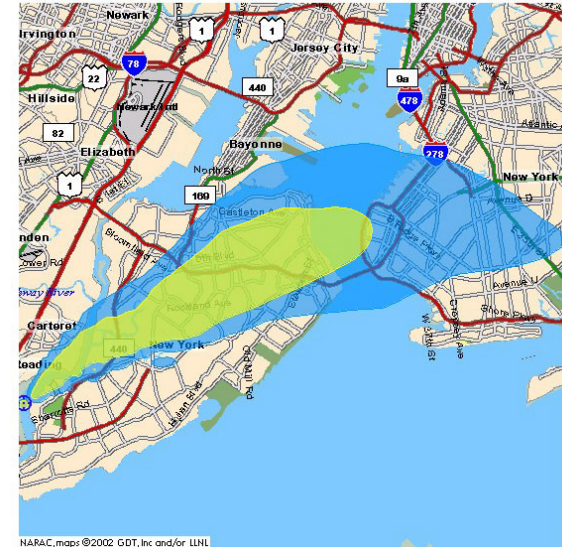
- **Operational applications** evaluate the usability, efficiency, consistency and robustness of models for operational conditions
- Examples: Chernobyl, Kuwait oil fires, tire fires, industrial accidents, Algeciras Spain Cesium release, Tokaimura criticality accident, Cerro Grande (Los Alamos) fire, post Sept 11 threats

# NARAC Supported NYC Office of Emergency Management During Staten Island Fuel Fire

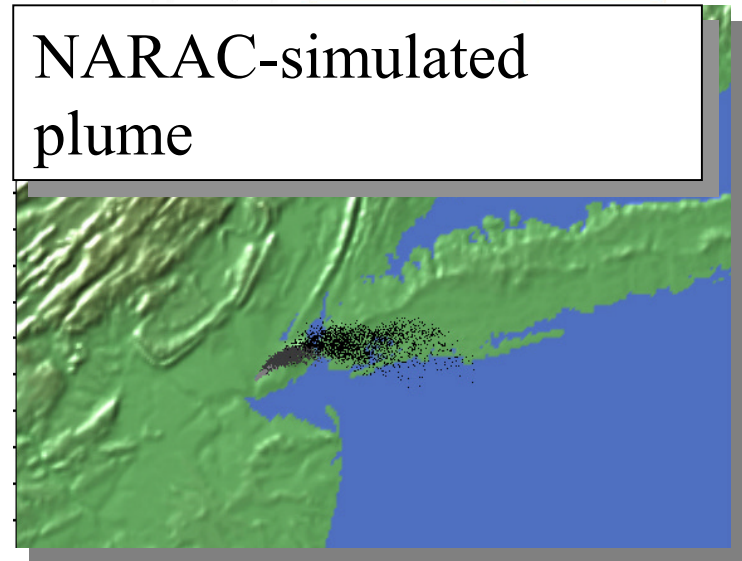


Staten Island Fuel Fire  
February 21, 2003

Satellite Photography



NARAC-simulated  
plume

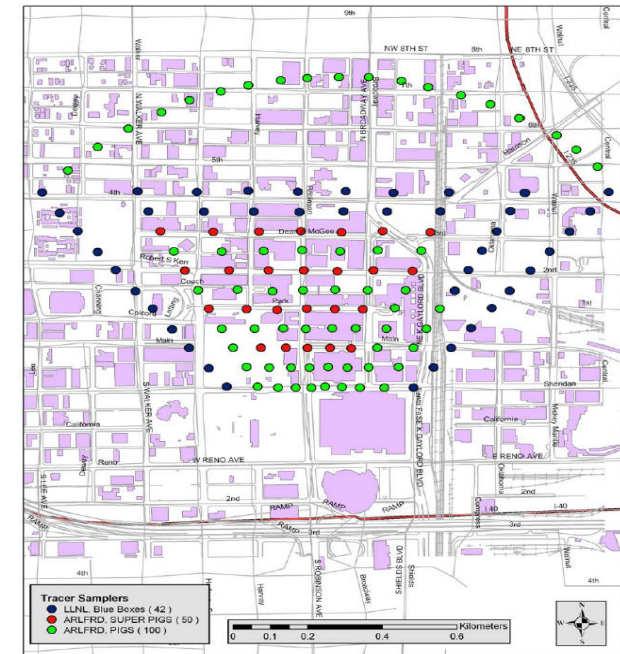
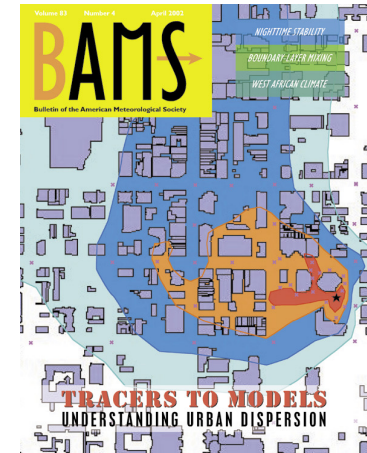




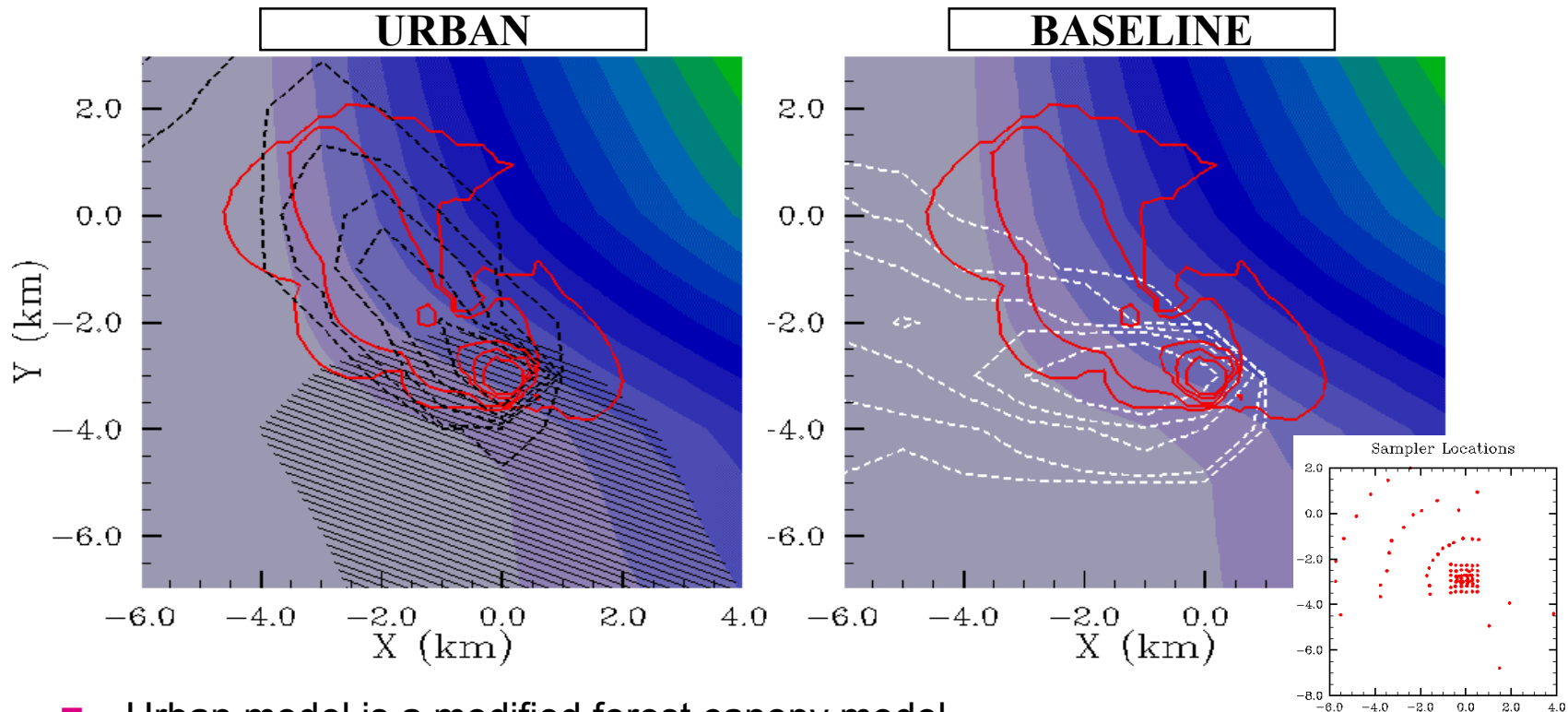
# Urban Field Studies are Crucial for Evaluation of Atmospheric Transport and Fate Models



- URBAN 2000 (Salt Lake City)
  - Data has been quality assured and released to the general scientific community
  - Nocturnal conditions (October, 2000)
- JU2003 (Oklahoma City)
  - Data collection completed (July, 2003)
  - Day and night time conditions, outdoor and indoor studies
- DHS Urban Dispersion Program (New York City)



# Regional model urban canopy parameterizations improve URBAN 2000 dispersion forecasts

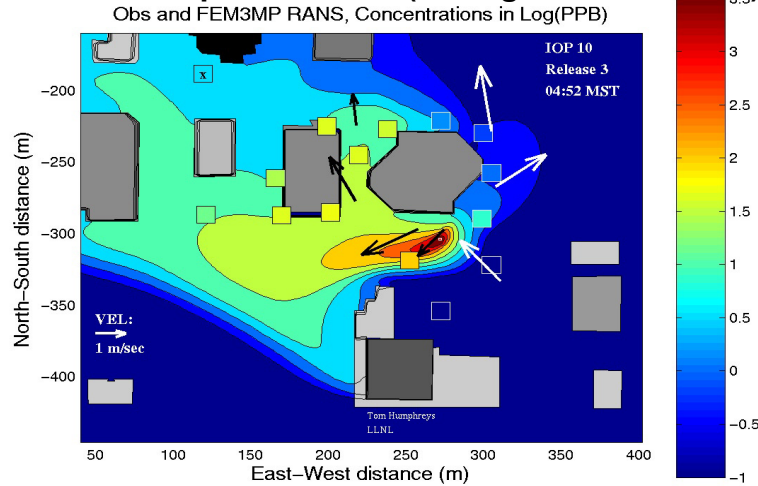


- Urban model is a modified forest canopy model (Brown & Williams 1998; Chin et al. 2000)
  - Friction source in momentum equation
  - Turbulence production in TKE equation
  - Anthropogenic heat source in potential temperature equation
- Observed (red contours) compared with COAMPS/LODI predictions of SF6 concentrations for IOP 10 release (4km resolution)

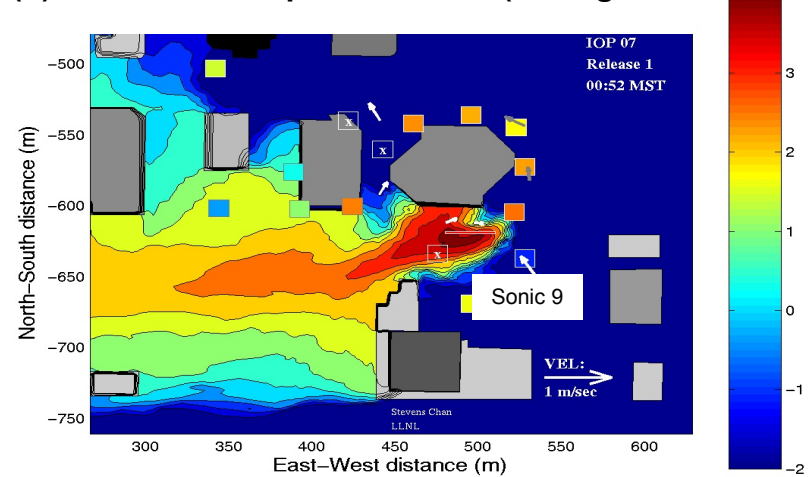
# Time-Dependent Boundary Conditions are Critical for LES in Light and Variable Conditions



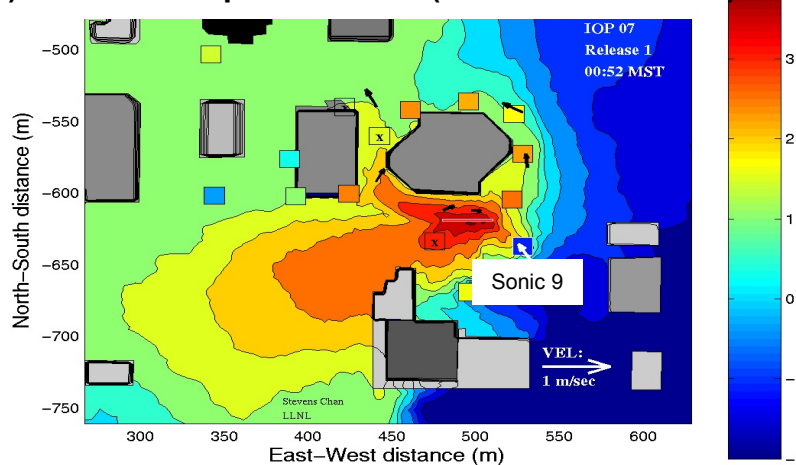
(a) IOP10 time-independent BCs (averaged sonic 9 data)



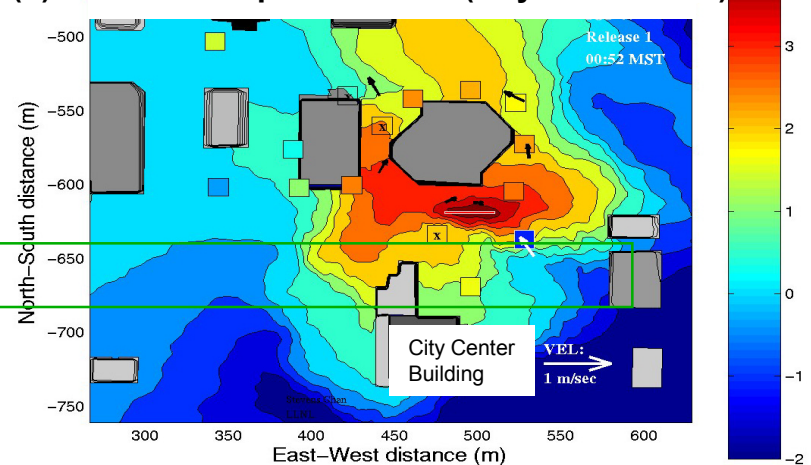
(b) IOP7 time-independent BCs (averaged sonic 9 data)



(c) IOP7 time-dependent BCs (actual sonic 9 data)

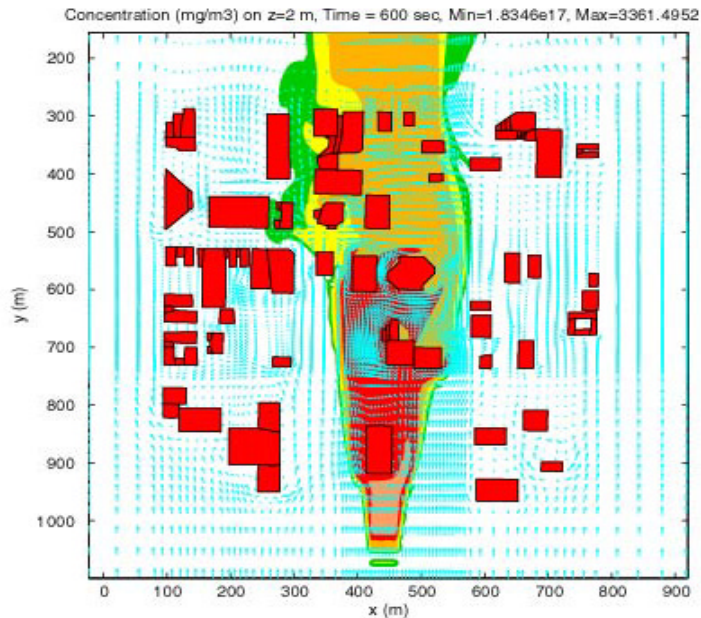


(d) IOP7 time-dependent BCs (City Center data)

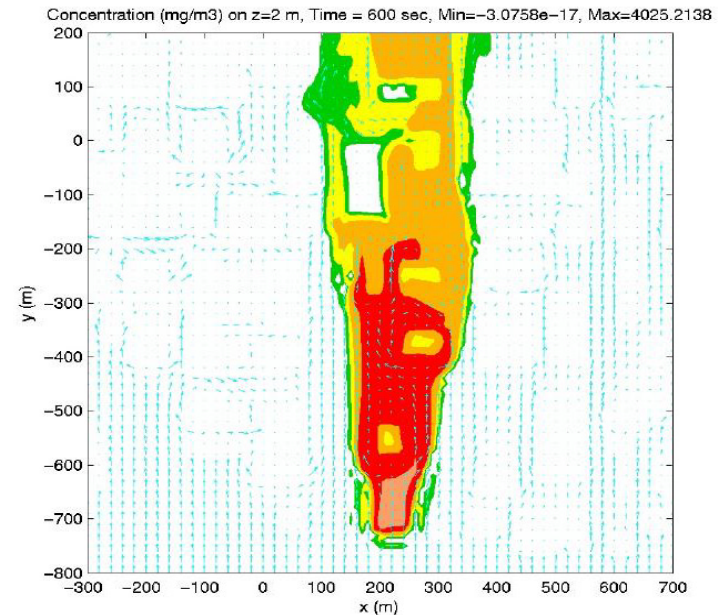
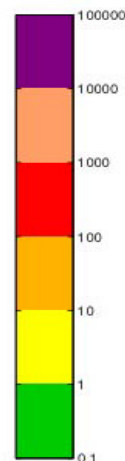
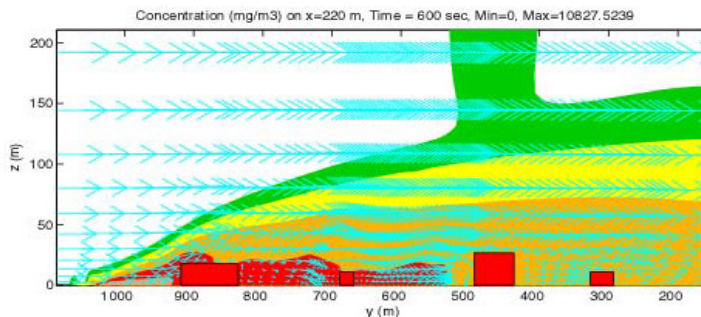




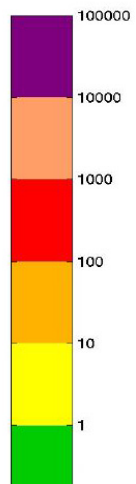
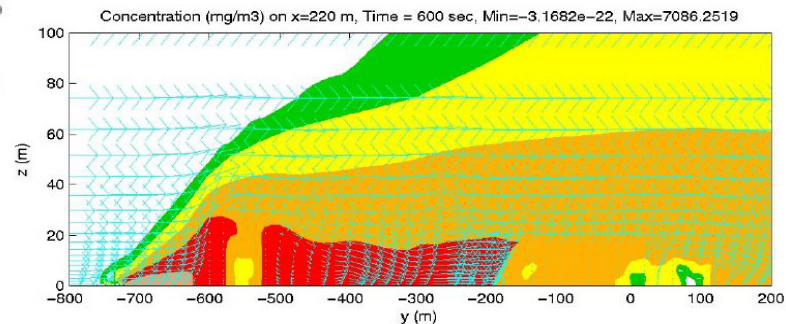
# Virtual Building Approach Provides an Order of Magnitude Speed-Up for Future Operations



**Fully-resolved results**



**Virtual representation**



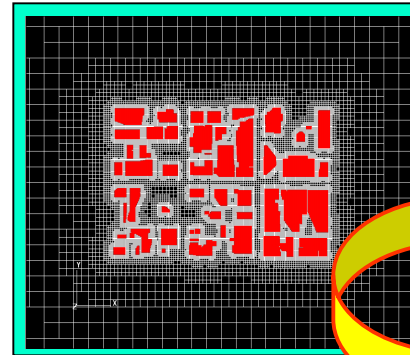


# Adaptive Dispersion Model (ADM) is NARAC's ext Generation Urban CFD Capability

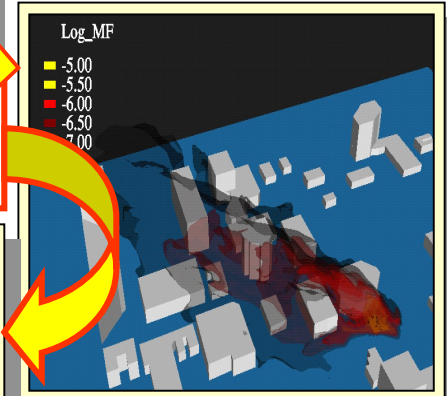


- Geometry-to-mesh capability
  - Efficient grid generation techniques (cut-cell and/or curvilinear overset grids)
  - Support of complex geometries (spaces (public facilities), subways, airplane bodies)
  - Adaptive mesh refinement
- Improved physics (radiation, surface heating, neutral density and dense gas physics, chemical kinetics)
- Advanced LES turbulence
- Coupling w/larger-scale models
  - Highly-resolved area nested in larger domain -> commensurate scales at boundaries
  - Forcing by larger scale flows
  - Time-dependent forcing (critical for variable wind conditions and/or fast-evolving plumes)

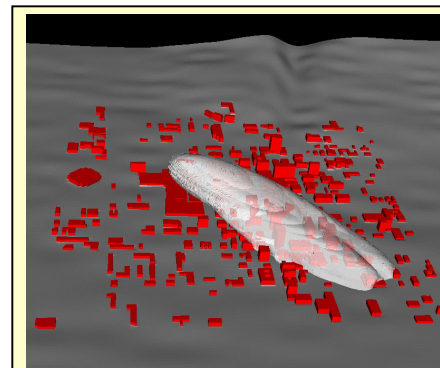
Rapid geometry-to-mesh and adaptive mesh refinement



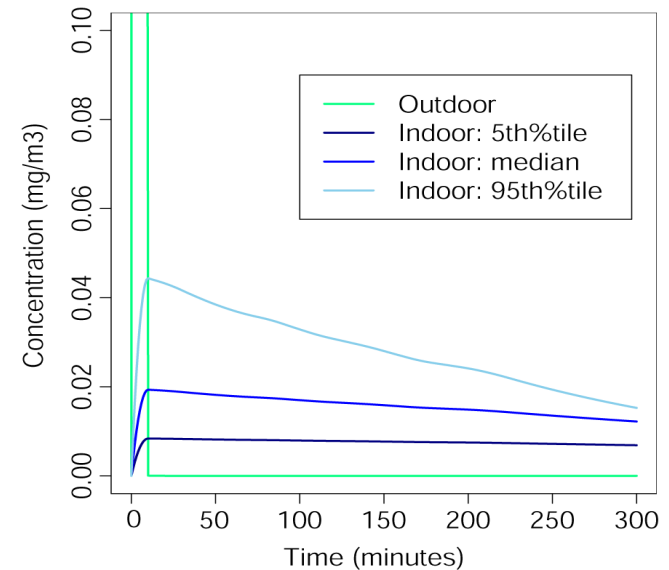
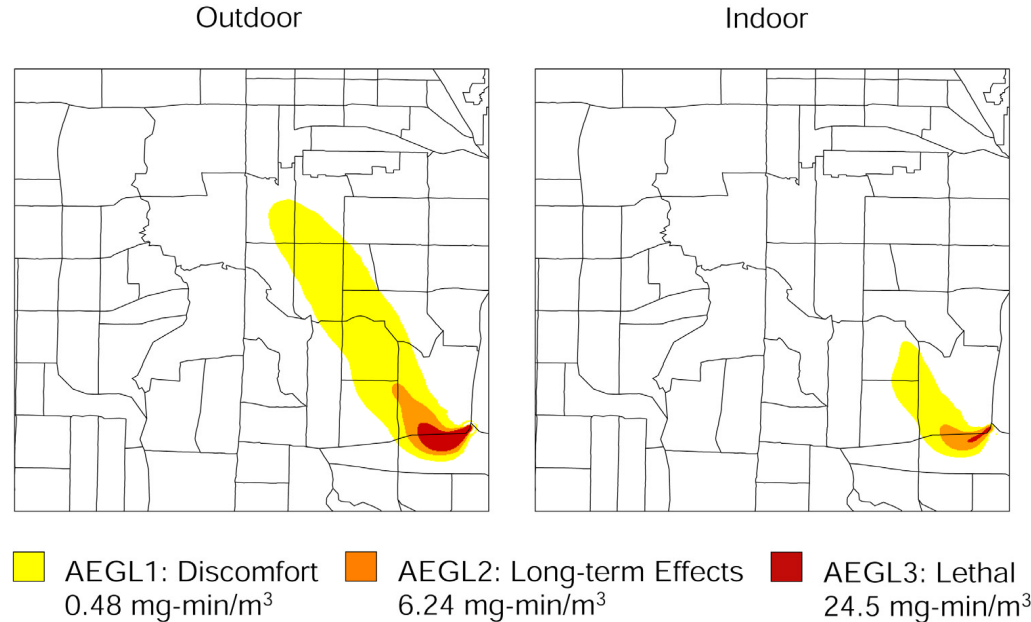
Cut-cell grids for complex geometries



Urban processes (turbulence, coupling)



Support for large-scale computer architectures

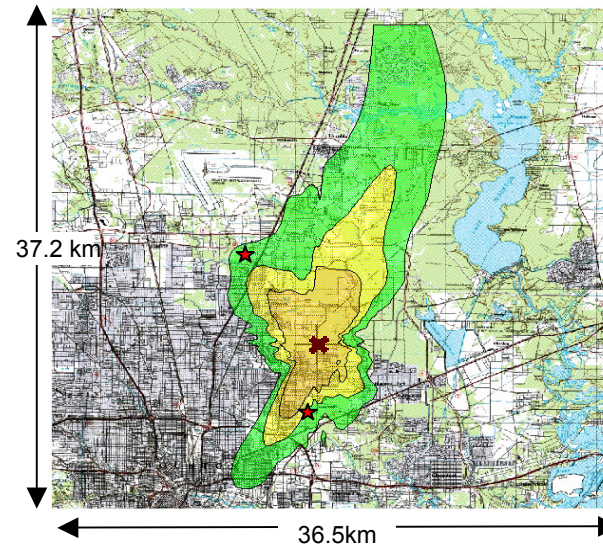


- Goal: Determine indoor exposures to guide evacuation / shelter-in-place
- Infiltration rate  $Q[m^3/s] = ELA \cdot \sqrt{f_w^2 \cdot \Delta T + f_s^2 \cdot U^2}$  [m<sup>3</sup>/s] (Sherman, 1980):
  - Effective leakage area (ELA) [m<sup>2</sup>]
  - Pressure force from U and  $\Delta T$
  - LBNL Residential air leakage building database
- Maximum indoor concentration << outdoor, but indoor levels higher longer-term

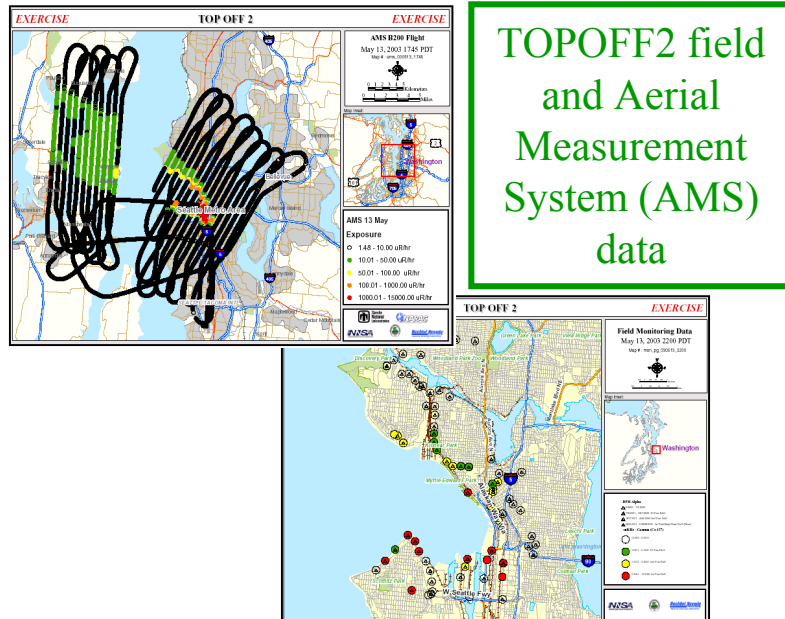
# NARAC is a Key Component of Detection, Warning, and Incident Characterization Systems



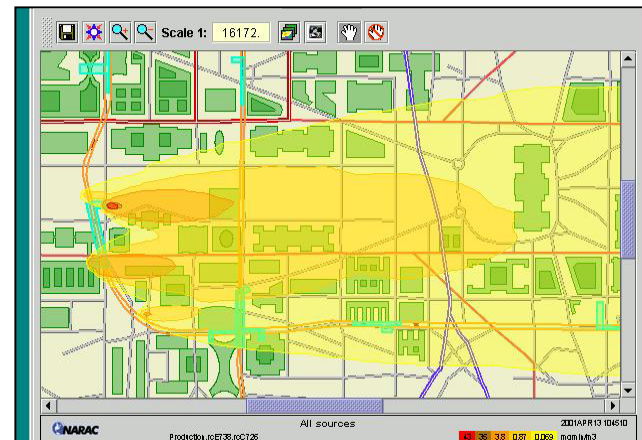
- DHS/HHS BioWatch environmental monitoring
- DHS Biological Warning and Incident Characterization System (BWIC)
- DOT/Wmata PROTECT subway chemical detection system
- DOE Nuclear Incident Response Team aerial and ground measurements



Analysis for  
environ.  
monitoring  
system

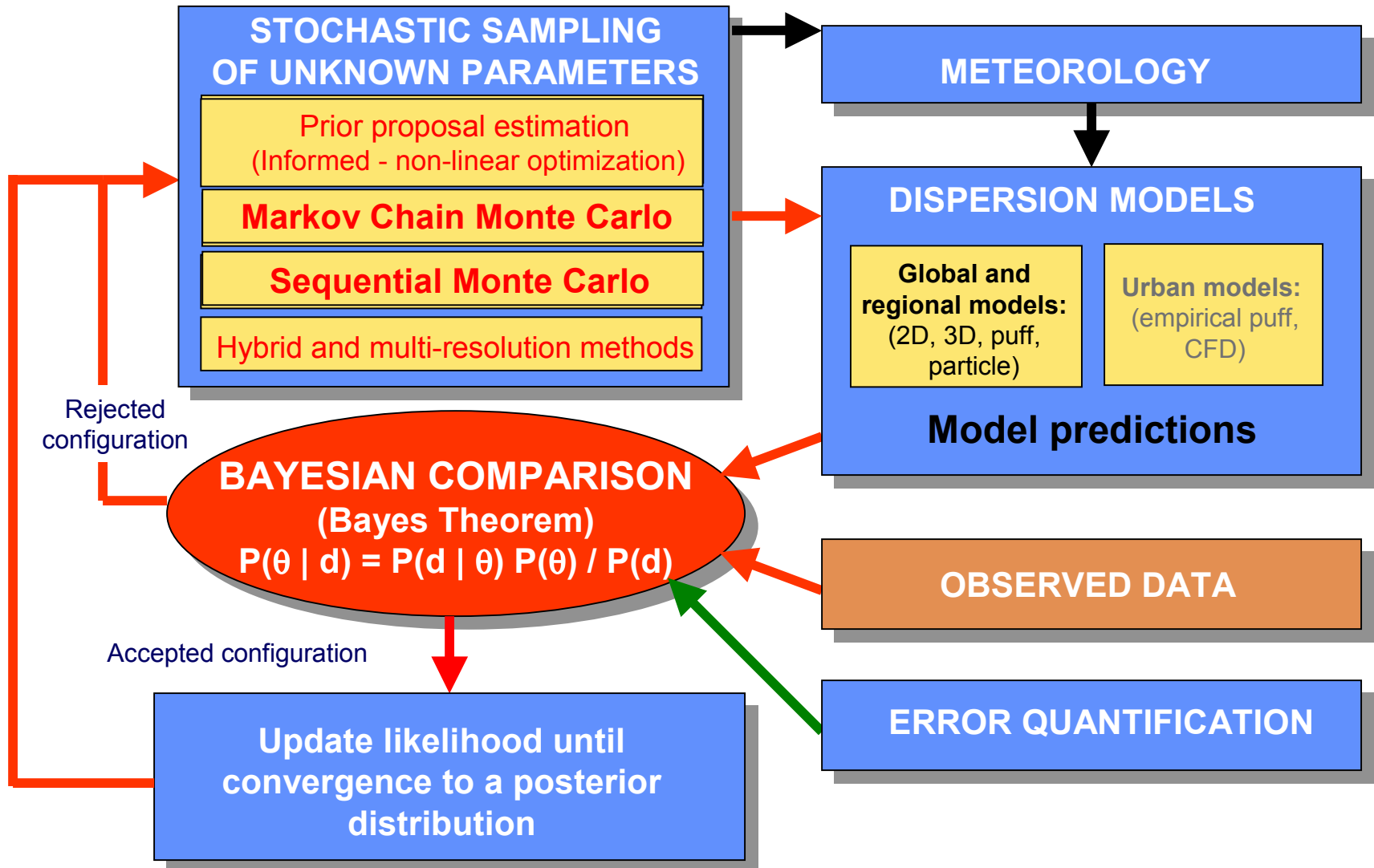


TOPOFF2 field  
and Aerial  
Measurement  
System (AMS)  
data



PROTECT  
subway  
crisis  
response  
system  
outdoor  
venting

# Event Reconstruction Answers the Critical Questions: What? When? Where? How Much?

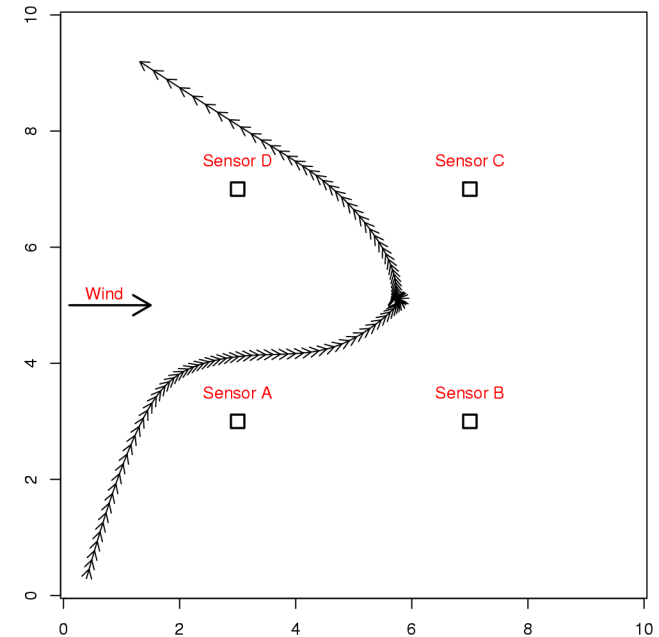


# Sequential Monte Carlo (SMC): Moving Vehicle Example Generated Using Synthetic Data



- Moving source in 10x10km domain
  - Variable speed and direction of source indicated by arrows
  - Vehicle remains stationary for a brief time at location near grid center
  - Synthetic truth generated by using 30s puffs at 120 equally spaced locations along line of movement
- SMC data provided for square sensor array
  - Synthetic measurement noise and model error introduced

$\text{Mean} = C, \text{SD} = 1e-10 + 0.1 * C$
- Prior/proposal distribution based on mixture of previous location and velocity
- SMC provides order of magnitude improvement in computational performance relative to classic Markov Chain Monte Carlo
- Tests against real-world data underway

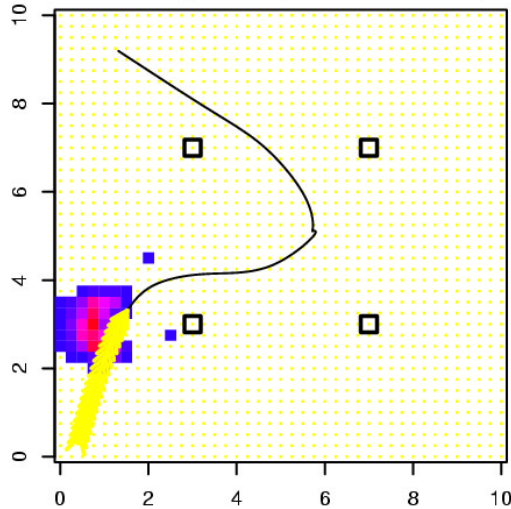




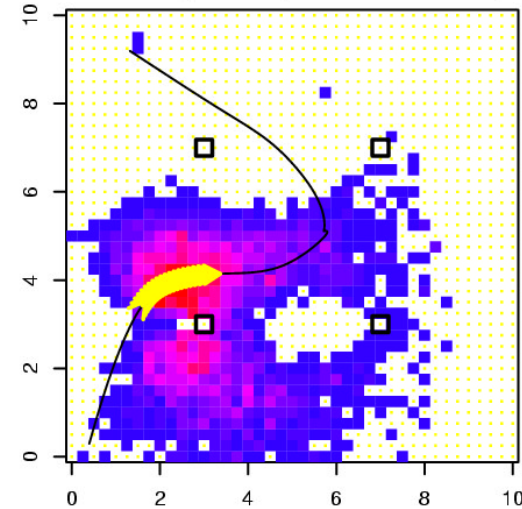
# SMC Determination of Moving Source Location From One Hour of Ten-Minute Averaged Data



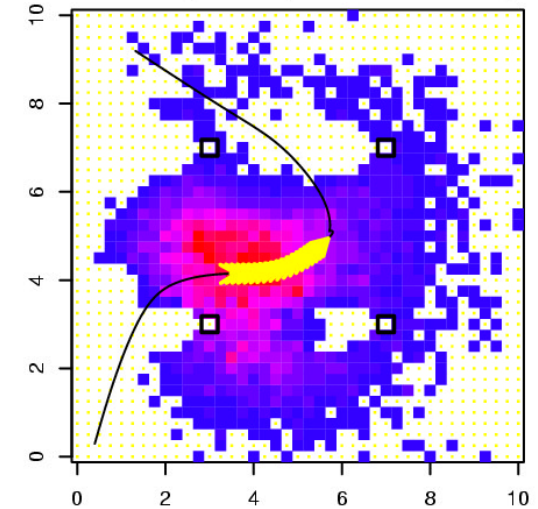
Source Location in the 0–10min interval



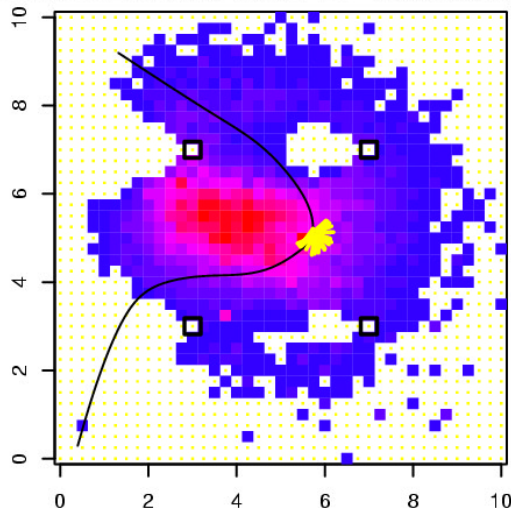
Source Location in the 10–20min interval



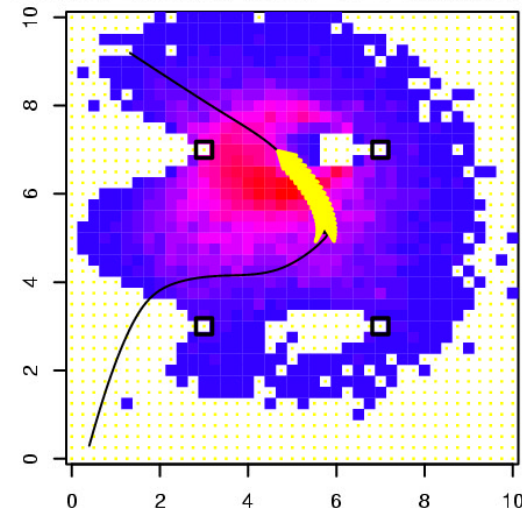
Source Location in the 20–30min interval



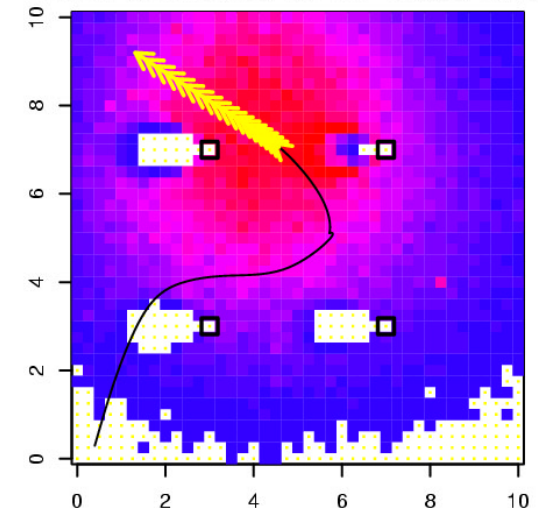
Source Location in the 30–40min interval



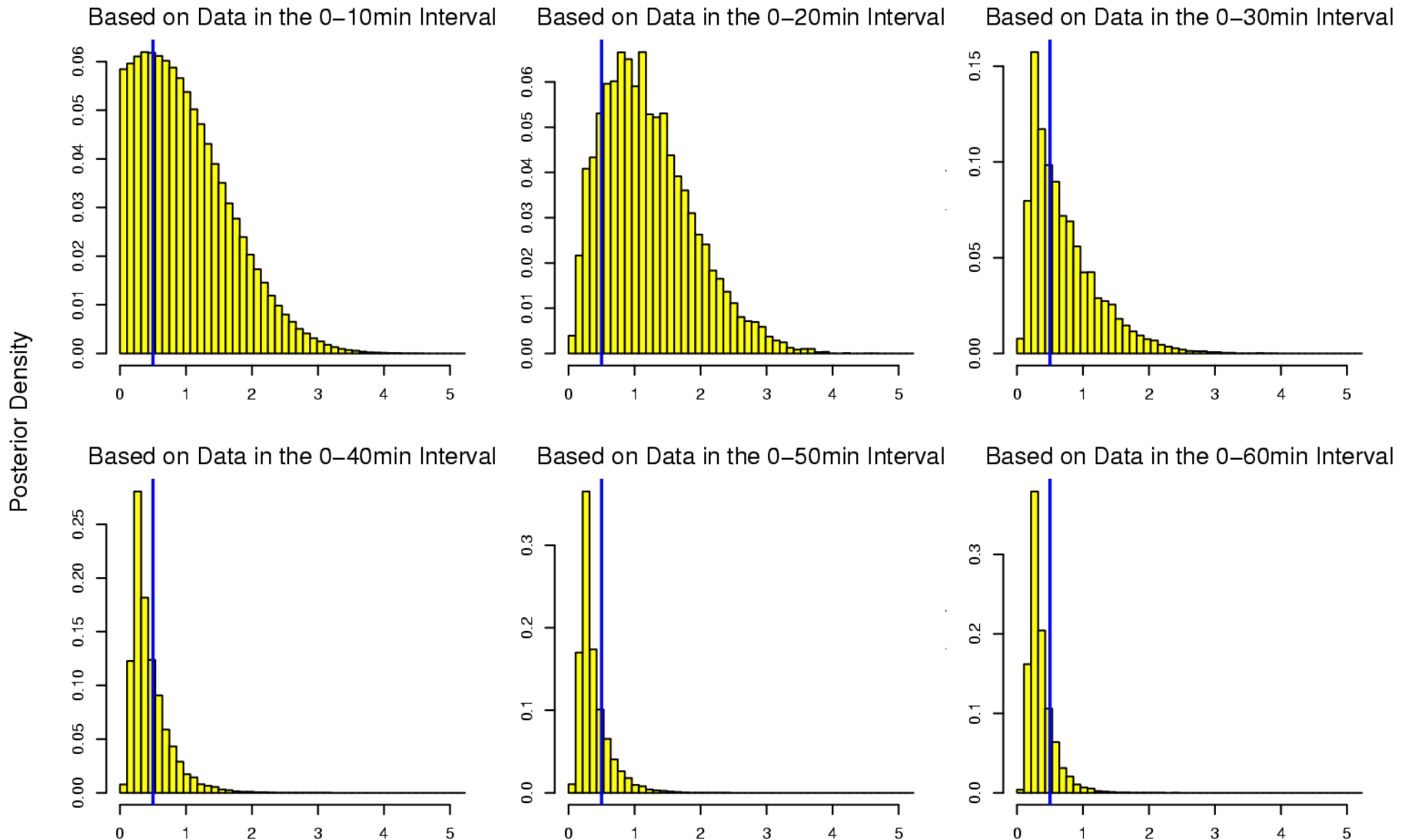
Source Location in the 40–50min interval



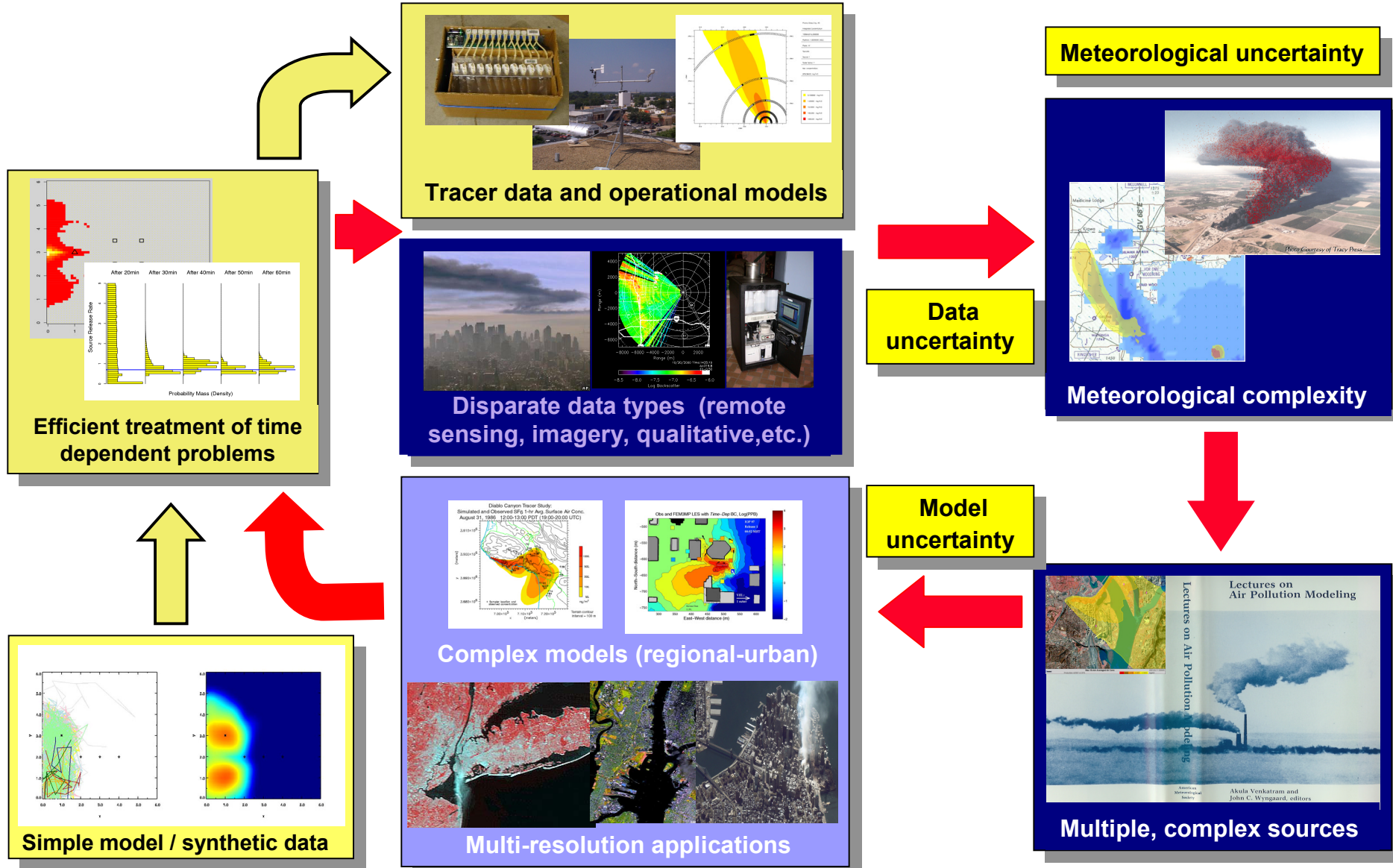
Source Location in the 50–60min interval



# SMC Simultaneous Determines Release Rate



# Event Reconstruction Must Address Problems of Increasing Complexity and Uncertainty





# NARAC Science Team and Collaborators

## Contributing to This Effort

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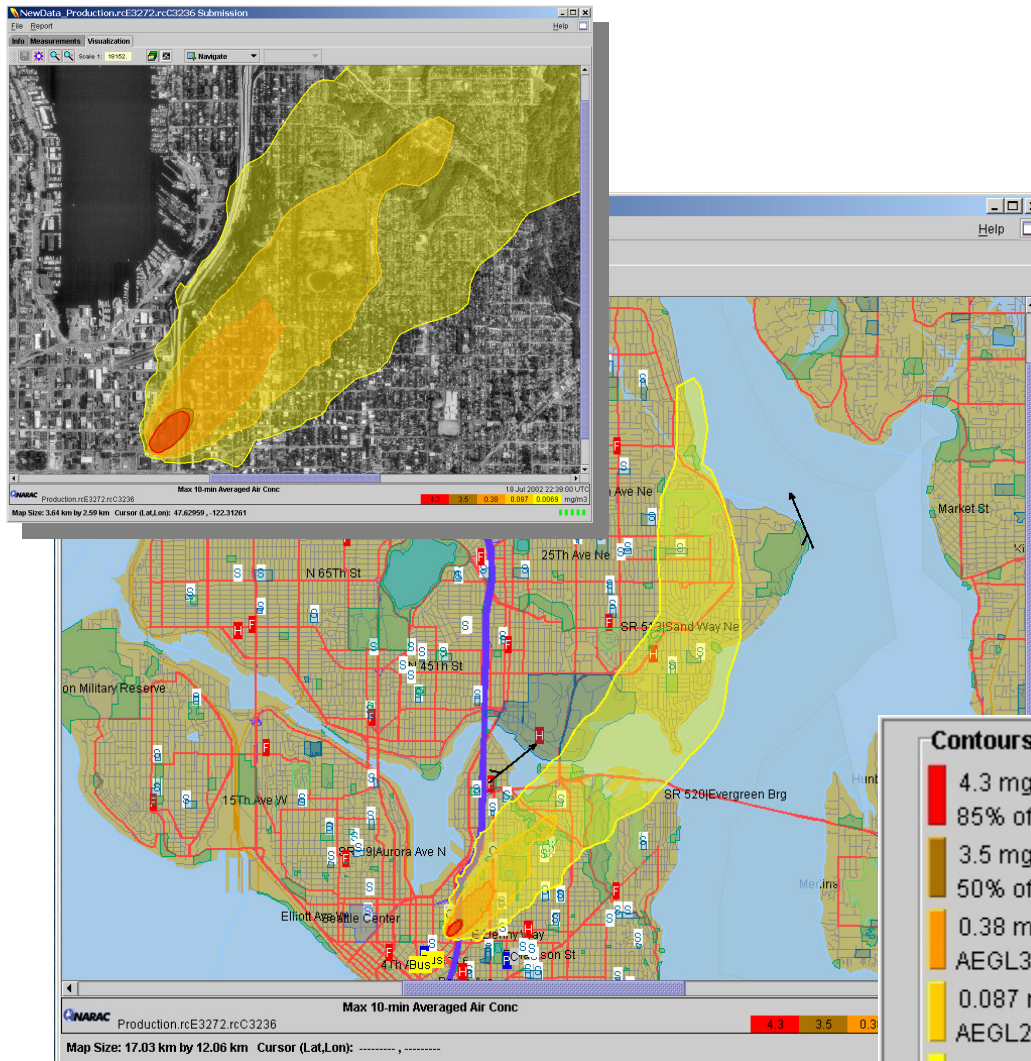
- Event Reconstruction: William Hanley, Gardar Johannesson, Branko Kosovic, Shawn Larsen, Gwen Loosmore, Julie Lundquist, Arthur Mirin, John Nitao, Radu Serban, Kathy Dyer (LLNL)
- Indoor Exposures/Building Infiltration
  - Ashok Gadgil, Wan Yu Chan, Phillip Price (LBNL) and William Nazaroff (UC Berkeley)
  - Hoyt Walker and Gwen Loosmore (LLNL)
- Rapid Response Models
  - ALOHA/CAMEO: Mark Miller et al.(NOAA)
  - UDM Integration: Ian Griffiths et al. (Dstl, MOD, U.K.)
- Subway System (PROTECT)
  - Tony Policastro et al. (ANL)
  - Bill Eme, Joe Guensche, Connee Foster, Bob Sheckman, Joe Tull (LLNL)
- Urban Field Studies (+ other institutions)
  - Jerry Allwine et al. (PNNL)
  - Martin Leach, Julie Lundquist, Joe Shinn, Frank Gouveia, Garrett Keating (LLNL)
- Urban CFD models: Stevens Chan, Branko Kosovic, Tom Humphreys, Bob Lee, Andy Wissink (LLNL)
- Urban NWP models: Martin Leach and Steve Chin (LLNL), Michael Brown (LANL)



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**BACKUP**

# NARAC Advisories Address the Needs of Emergency Managers and First Responders



- Hazard areas
- Affected population
- Health effects
- Protective Action Guidelines (PAGs)
- GIS and map features
- Wind observations and fields

## Contours

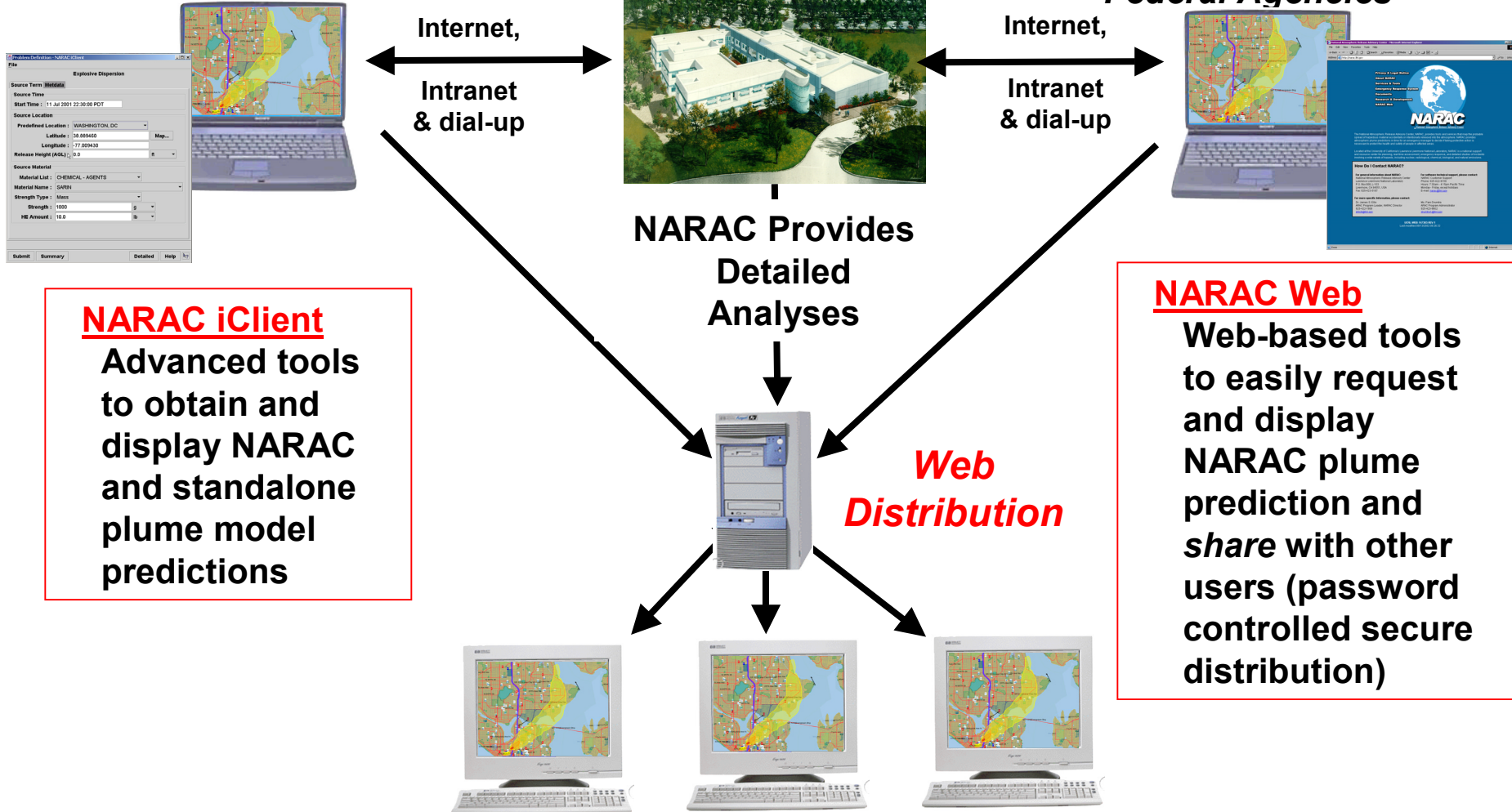
- 4.3 mg/m<sup>3</sup> Area: 0.038 sq km Population: 30  
85% of the exposed population could receive a lethal dose.
- 3.5 mg/m<sup>3</sup> Area: 0.046 sq km Population: 30  
50% of the exposed population could receive a lethal dose.
- 0.38 mg/m<sup>3</sup> Area: 0.378 sq km Population: 3356  
AEGL3: Exposed population could experience life-threatening effects.
- 0.087 mg/m<sup>3</sup> Area: 1.450 sq km Population: 7482  
AEGL2: Population could experience serious long-lasting effects.
- 0.0069 mg/m<sup>3</sup> Area: 15.249 sq km Population: 33001  
AEGL1: Exposed population could experience notable discomfort.

# Remote Access to NARAC is Provided Via Internet- and Web-based Tools



**Federal & State Response Teams and Hub Cities**

**Cities, Counties, State & Federal Agencies**

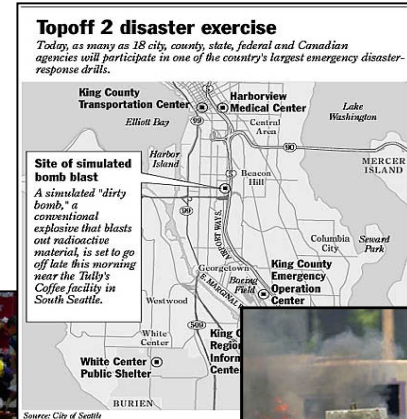




# DHS Local Integration of NARAC with Cities (LINC) Project



- TOPOFF 2 exercise (May 12-15, 2003)
  - Hypothetical RDD release scenario
  - Largest terrorism exercise undertaken since the terrorist attacks of September 11, 2001
  - Seattle (Fire Dept and EOC), King County, Washington state
  - 19 federal agencies, including DHS and DOS
- Staten Island Barge Fire (Feb 21, 2003)
  - NYC Office of Emergency Management
  - Guidance for deployment of emergency responders and field monitoring teams
  - Real-time plume prediction of affected areas and population
  - Health-risk levels for 1 and 24 hour exposures



TOPOFF 2



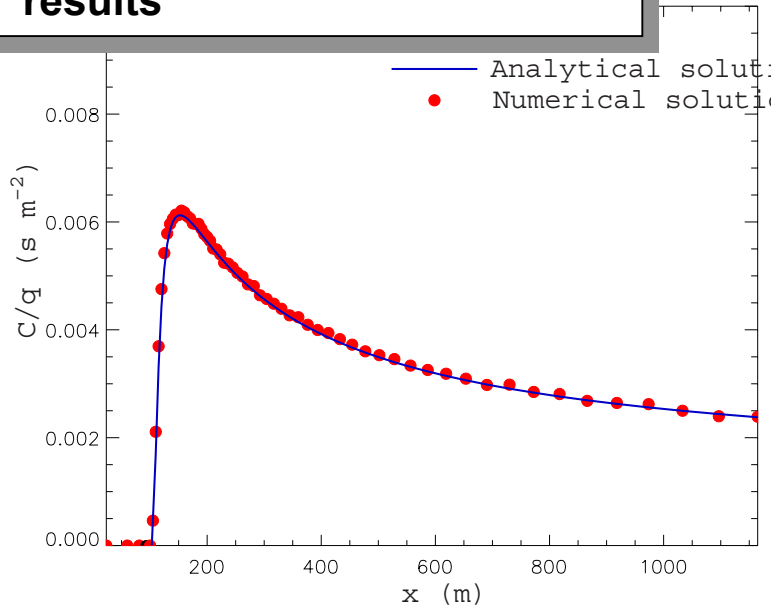
NYC Barge Fire



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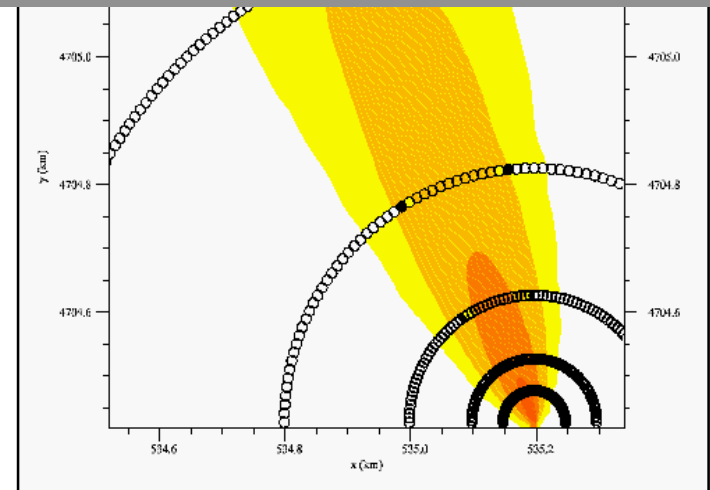


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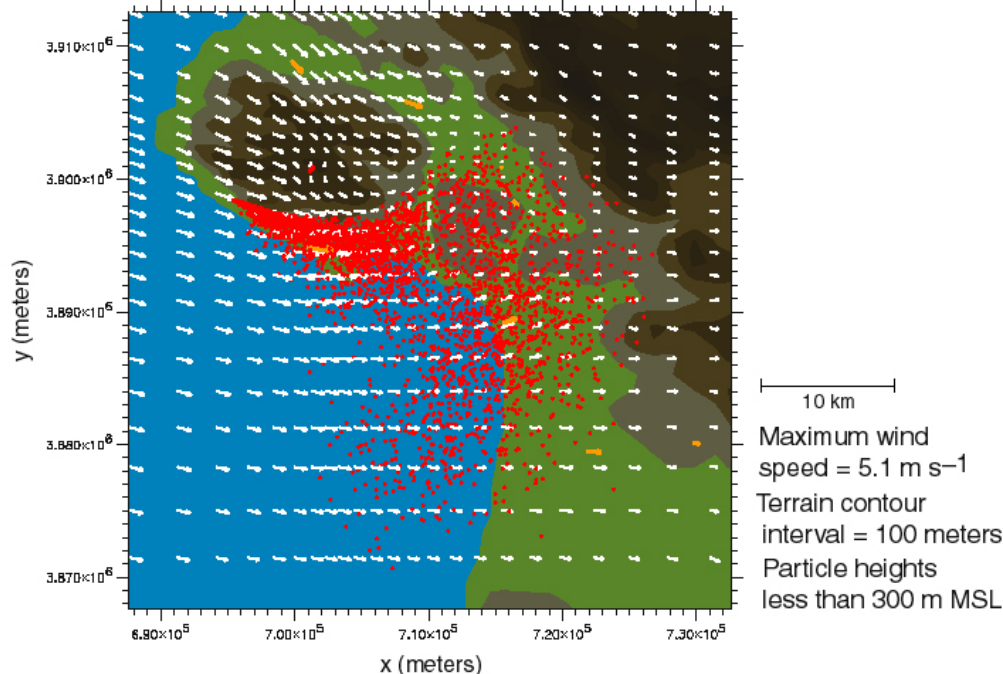


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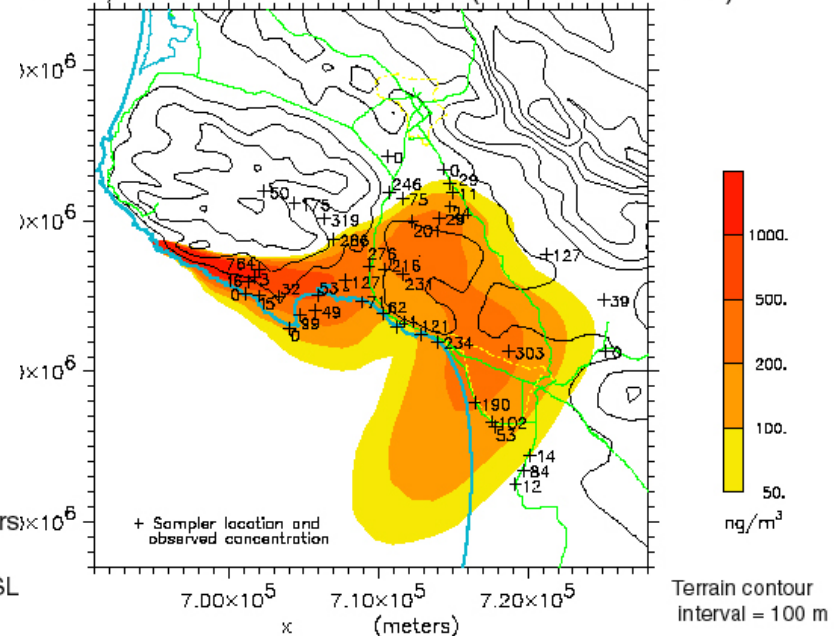
# Diablo Canyon Power Plant Tracer Experiment (DOPPTEx) Shows Effect of Complex Terrain



Diablo Canyon Tracer Study: August 31, 1986  
Simulated (x,y) particle positions, 12:00-13:00 PDT (19:00-20:00 UTC)  
Simulated 10-m AGL wind field 11:45 PDT



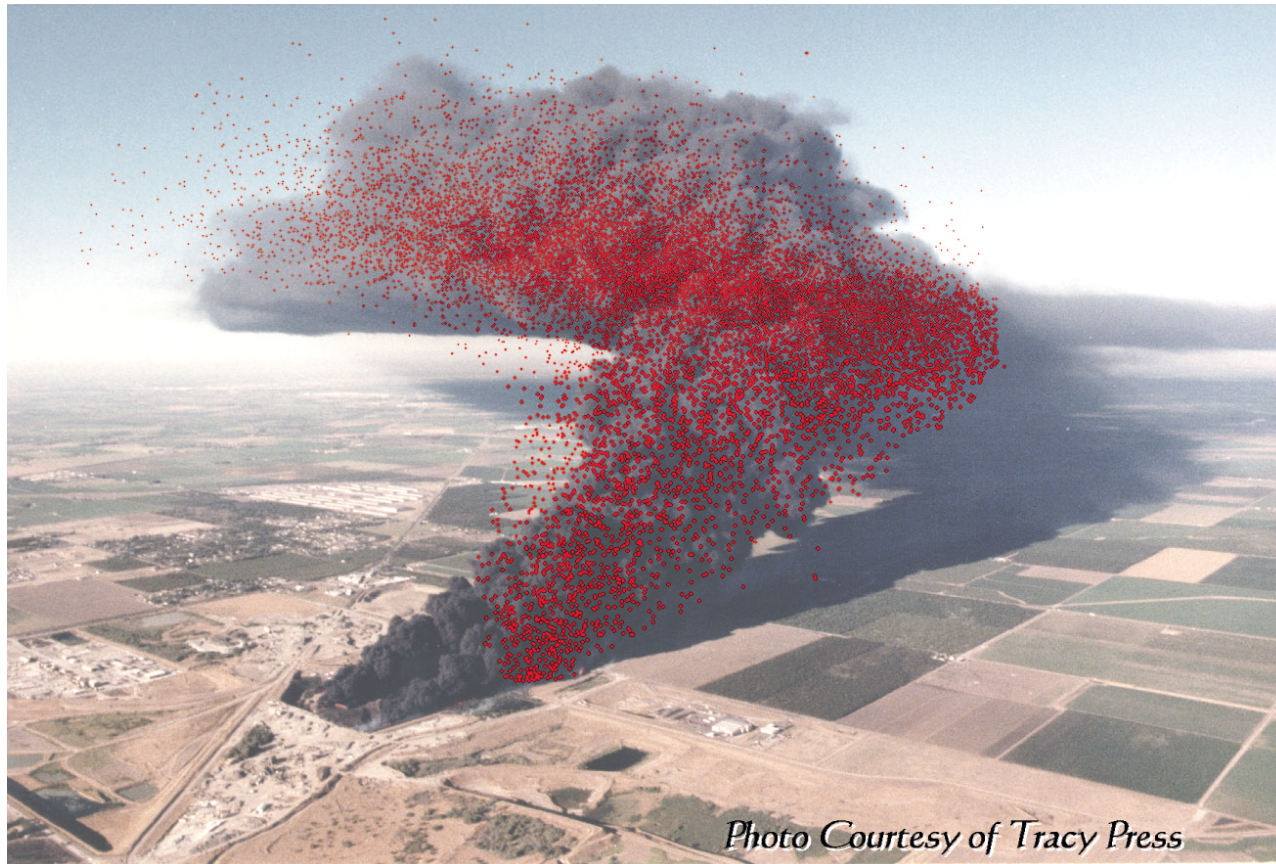
Diablo Canyon Tracer Study:  
Simulated and Observed SF<sub>6</sub> 1-hr Avg. Surface Air Conc.  
August 31, 1986 12:00-13:00 PDT (19:00-20:00 UTC)



- Hilly, coastal terrain near San Luis Obispo, CA (31 August – 17 September, 1987)
- Continuous and pulsating SF<sub>6</sub> tracer releases at surface and 71m
- 18 surface stations and 3 sodars, providing vertical wind structure at 15 minute intervals
- One-hour averaged air concentrations 1- 40km downwind



# NARAC Provides Real-Time Advisories for Hazardous Atmospheric Releases



*Photo Courtesy of Tracy Press*

**Tire Dump Fire Tracy, California**

***August 7, 1998***

**Photograph of smoke plume overlaid LODI-simulated particle positions (in red)**

## **Major responses**

- **Staten Island, NY**
- **September 11<sup>th</sup>, 2001**
- **Cerro Grande, NM**
- **Richmond, CA**
- **Algeciras, Spain**
- **Desert Storm, Kuwait**
- **Mt. Pinatubo Volcano**
- **Tokaimura, Japan**
- **Chernobyl**
- **Three-Mile Island**



# Computational Framework Will Support Multiple Stochastic Algorithms, Models, and Platforms

